PAN-PACIFIC ENTOMOLOGIST
63(3), 1987, pp. 218–223

Phenology of Douglas-Fir Tussock Moth, *Orgyia pseudotsugata*, Egg Eclosion and Mortality in a Thinned and Unthinned Stand (Lepidoptera: Lymantriidae)

BOYD E. WICKMAN AND TOROLF R. TORGERSEN

Forestry and Range Sciences Laboratory, Pacific Northwest Research Station, Forest Service, U.S. Department of Agriculture, La Grande, Oregon 97850

Abstract.—Heat-unit accumulation and egg eclosion were monitored in unthinned and thinned white fir stands in southern Oregon. Degree-day accumulation and egg eclosion on the unthinned site were 7 to 10 days behind development in the thinned site. Parasitism and predation were higher on egg masses in the thinned stand.

The ability to predict phenological development of insect-host systems has important applications for pest management as well as for research on population biology. Studies on phenology of the Douglas-fir tussock moth, *Orgyia pseudotsugata* (McDunnough), in California and Oregon (Wickman 1976a, 1976b, 1981) show egg eclosion is synchronous with host budburst. During population sampling for early instars, we observed a spread in developmental stages from 1st to 3rd instars on some sites. Phenological data suggest that egg eclosion on a given site is related to the amount of solar radiation reaching an egg mass; eclosion usually occurs first in the exposed tops of large trees and last in shaded areas under full forest canopy (Wickman 1976b).

In the past, we compared tussock moth egg masses only from exposed trees but at different elevations (Wickman 1976a, 1976b, 1981). Egg eclosion was assumed to be early on exposed trees, and later in shaded habitats. In this study, our object was to compare tussock moth eclosion and egg mortality in two different environments at the same elevation—a thinned (exposed) and an adjacent unthinned (shaded) stand.

The study was limited by available sites, egg masses, and instrumentation. These preliminary data are reported to encourage more definitive studies on the effects of silvicultural prescriptions on insect phenology and mortality.

METHODS

The study site was near Mare's Egg Spring, 10 km southwest of Fort Klamath, in south-central Oregon. The site, with an eastern exposure, is at 1350 m elevation and on a level bench about 100 m above the upper Klamath basin. The site was partly on a population-study plot used for phenological monitoring of tussock moth from 1976–80 (Wickman 1981).

One exposed and one shaded habitat were compared. The exposed habitat was in a thinned stand of second-growth white fir (*Abies concolor* (Gordon and Glend.) Lindley ex Hildebr.) with widely spaced saplings and pole-sized trees and a few overstory ponderosa pine (*Pinus ponderosa* Douglas ex Lawson). The shaded habitat, about 100 m to the east, was a dense, unthinned, second-growth white fir stand of pole-sized trees with a closed canopy.

Temperature was recorded in the thinned stand by a 31-day battery-powered, weather-sheltered hygrothermograph from November 1976 to November 1977. From these records, Fahrenheit degree-day (°D) accumulations were calculated for the exposed environment. The heat-unit threshold for development selected was 5.6°C (42°F) Wickman 1976a). When budburst began on May 31 in the area, a weather-sheltered, 7-day hygrothermograph was installed in the unthinned stand; monitoring continued until July 5. The °D accumulations for the two stands were compared from June 1 to July 5.

Because natural populations of Douglas-fir tussock moth in the area were low and egg masses difficult to find, we used egg masses reared in the laboratory from larvae collected locally in June 1976. The egg-mass stock, which was also used for other population studies (Torgersen and Ryan 1981), showed normal fecunditv and development. The egg masses ranged from 100 to 250 eggs ($\bar{x}$ = 150).

To acclimate the egg masses, they were randomly divided into two batches, placed in fine-mesh nylon bags, and hung in both stands on February 9. On April 5, egg masses were individually wired to branches (Torgersen and Mason 1979). One egg mass was wired at about 2 m from the ground at the four cardinal directions on four trees, for a total of 16 egg masses in each stand. In the thinned stand, the masses were wired to the underside of live, lower crown foliage. Because not much foliage was present at 2 m in the unthinned stand, the masses were placed on small, foliated adventitious branches on the main trunk at that height. Egg masses occur naturally in such locations, as well as on large foliated branches. A 30- × 60-cm fine-mesh nylon bag was placed over each stocked branch to prevent predation, although the mesh did not keep out parasites. Bags were left in place until June 6. Masses were checked every 2 days from June 6–12, and then daily through July 5. Each morning, egg eclosion was recorded and new larvae counted and removed. On July 5, the egg masses were removed for further rearing in the laboratory at 20°C. Each egg mass was dissected when eclosion was complete and parasites ceased to emerge. Emerging adult parasites were counted daily, and egg numbers were recorded. Unbroken eggs from which neither tussock moth larvae nor parasites emerged were recorded as "unknown mortality" (Torgersen and Mason 1979).

Results and Discussion

A steady divergence of °D accumulation is evident between the thinned and unthinned stands (Fig. 1). On June 20 when eclosion began in the thinned stand, °D reached 432 (from June 1), and 282 °D had accumulated in the unthinned stand—a difference of 150 °D. By July 5, thermal development on the two sites had diverged by 285 °D. These °D differences between thinned and unthinned stands at the same elevation were greater than those found between two exposed sites with a 100 m difference in elevation (Wickman 1981). Hopkins' (1918) "bioclimatic law" states that natural development is delayed 4 days for each 400 ft (122 m) rise in elevation at a given latitude. Thus, local variation in °D development resulting from thinning may surpass elevational differences of as much as 100 m.

The mean °D accumulation in the unthinned stand from June 1 to 20 was 14 °D/day. Therefore, °D accumulation in the thinned stand was about 11 days ahead of the unthinned stand. Egg masses in the unthinned stand were exposed to predation for nearly 2 weeks longer than eggs in the thinned stand.

Egg eclosion differed on the two sites (Fig. 1), consistent with the previous finding

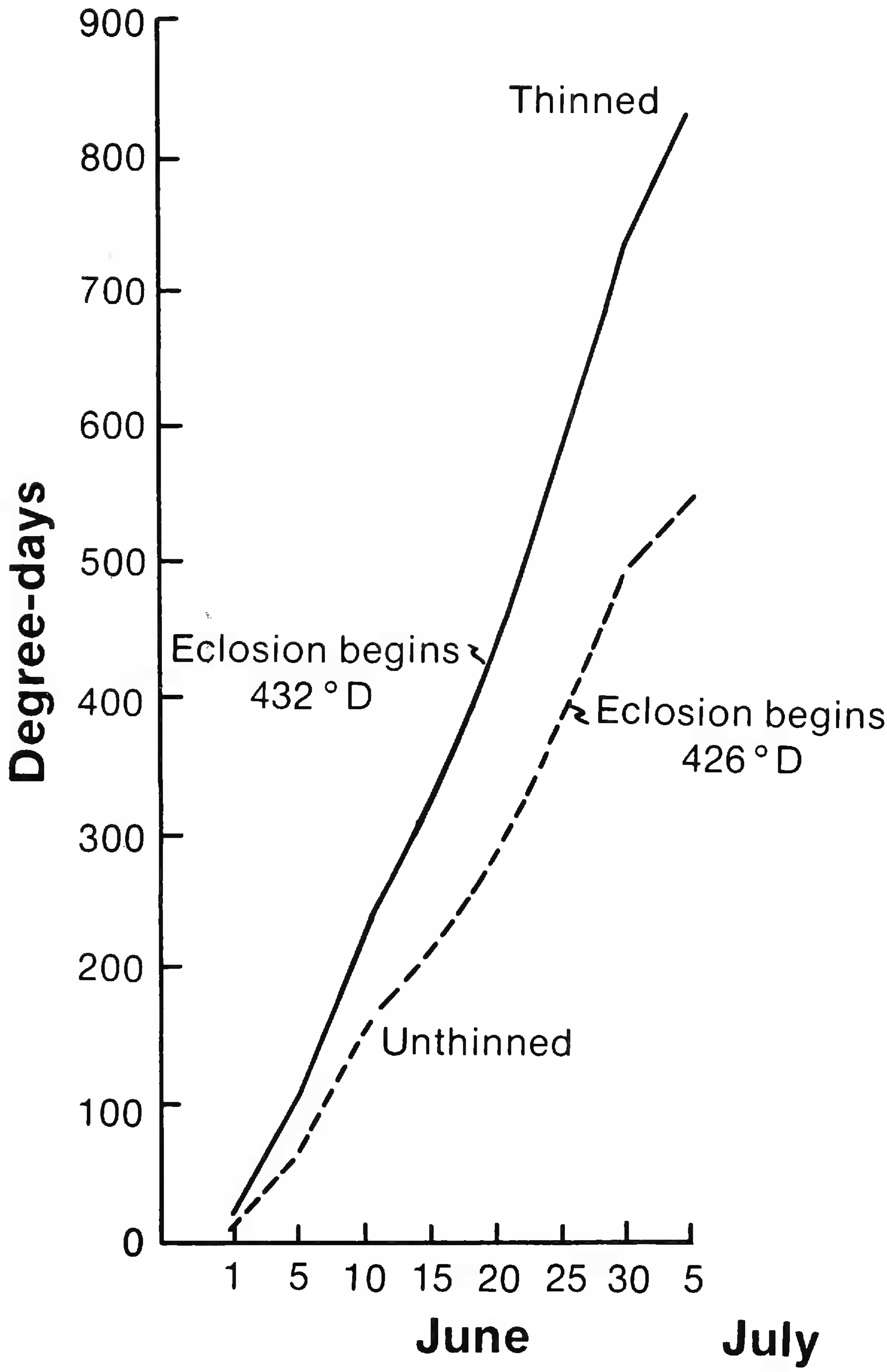

Figure 1. Accumulated degree-days in thinned and unthinned stands in south-central Oregon, 1977.

that hatch of tussock moth eggs is influenced by exposure to solar radiation (Wickman 1976a). Egg eclosion began on June 20 in the thinned stand and was 99 percent complete on July 5. Eclosion did not begin in the unthinned stand until June 27 and was only 61 percent complete on July 5. Eclosion from eggs in the unthinned stand continued for 10 days in the laboratory.

The mesh bags around the egg masses did not prevent heavy attack by the egg parasite *Telenomus californicus* Ashmead in the early spring. In another study,

Table 1. Douglas-fir tussock moth egg eclosion, *Telenomus californicus* emergence, and unknown mortality in a thinned and unthinned stand, south-central Oregon, 1977.

	Eggs per mass	Douglas-fir tussock moth eclosion	*Telenomus californicus* emergence	Unknown mortality	Parasitism	Unknown mortality
	Number				Percent	
Thinned						
Total		298	943	392		
$\bar{x}$	101.9				61.9	15.9
S.D.	47.83				22.06	22.16
Unthinned						
Total		781	1072	362		
$\bar{x}$	138.4				48.9	17.8
S.D.	52.75				14.75	17.44

females of this tiny parasite were first observed on egg masses at nearby Mare's Egg Spring plots on April 1, and parasite oviposition was essentially completed by April 20 (Torgersen and Ryan 1981).

In our study, egg masses were also heavily parasitized, averaging 61.9 percent in the thinned stand and 48.9 percent in the unthinned stand (Table 1). Parasites began to emerge from egg masses in the unthinned stand 6 °D later, lagging behind the thinned stand; emergence ceased on the same day in both stands, however (Fig. 2). Emergence of *T. californicus* can be roughly predicted from heat-unit accumulation. In the combined field and laboratory rearing, emergence was completed at 1,635 °D, accumulated from April 1 to July 24. This included 468 °D accumulated in the laboratory—26 °D daily for 18 days.

Higher parasitism in the thinned stand (Table 1) suggests either that the parasites do more searching in exposed tree crowns than in closed canopies or that some other environmental condition draws them there.

The egg masses were exposed to predators from June 6 to July 5. Torgersen and Mason (1979, 1985) found that birds and ants can partially destroy or completely remove egg masses, and about half the eggs can be lost from predation by birds alone. They also found significantly greater egg parasitism on xeric than on mesic plots in California, Oregon, and Idaho.

In our study, egg masses appeared to be about the same size when we placed them in the field. On July 5, masses from the thinned stand had one-third fewer eggs than those from the unthinned stand and looked broken and ragged, which is typical of predation.

A t-test showed that the differences in egg survival, after parasitism and apparent predation between thinned and unthinned stands, were significant ($p = < 0.05$). The difference between the two sites in unknown egg mortality was not significant, however. As expected, egg viability was similar ($p = > 0.05$) because the egg masses came from the same natural population.

Thinning increases the exposure of host trees to solar radiation and affects °D accumulation, which speeds tussock moth egg development and eclosion. Thus,

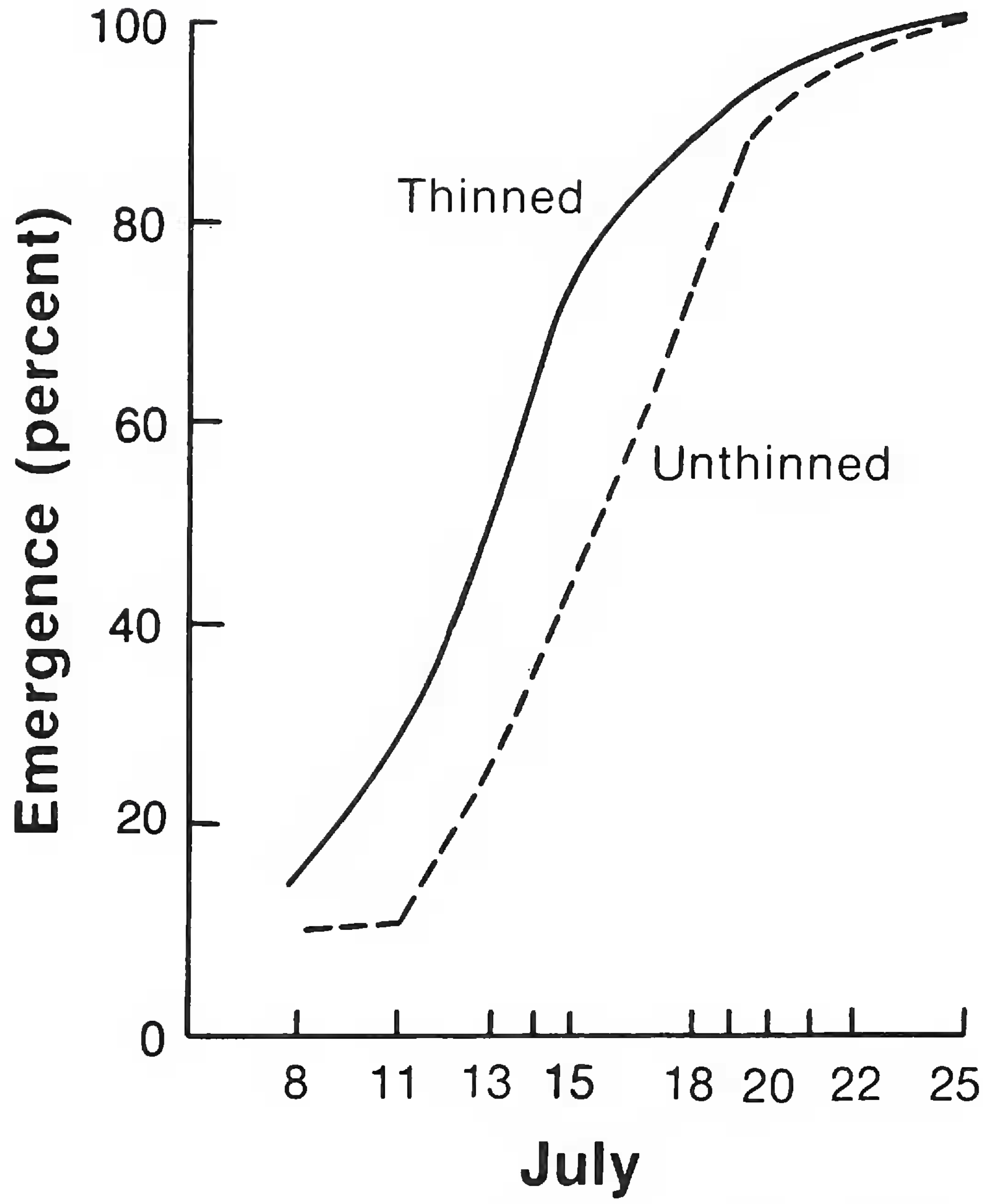

Figure 2. Accumulated percentage emergence of *Telenomus californicus,* from Douglas-fir tussock moth egg masses in thinned and unthinned stands in south-central Oregon, 1977.

some survival advantage could be gained by egg deposition in open stands, where eggs might be exposed to predation for 14 fewer days. Thinning also apparently enhances predation by birds and ants and parasitism by *T. californicus.* These limited data leave unclear whether the advantages of earlier egg eclosion and reduced length of exposure to predation can be offset by greater intensity of predation and higher parasitism. More study is needed to measure precisely the effects of thinning on the population dynamics of the tussock moth and other defoliating insects.

Acknowledgments

This study was funded in part by the USDA Expanded Douglas-fir Tussock Moth Research and Development Program, Portland, Oregon. We thank Sherry Gollob and Lee Roe for their assistance in the field and laboratory.

Literature Cited

Hopkins, A. D. 1918. Periodic events and natural laws as guides to agricultural research and practice. USDA Mon. Weather Rev. Suppl. 9:42.

Torgersen, T. R., and R. R. Mason. 1979. Predation and parasitization of Douglas-fir tussock moth egg masses. USDA Handb. 549. 11 pp.

Torgersen, T. R., and R. B. Ryan. 1981. Field biology of *Telenomus californicus* Ashmead, an important egg parasite of Douglas-fir tussock moth. Ann. Entomol. Soc. Am. 79:185–186.

Torgersen, T. R., and R. R. Mason. 1985. Characteristics of egg parasitization of Douglas-fir tussock moth, *Orgyia pseudotsugata* (McD.) (Lepidoptera: Lymantriidae), by *Telenomus californicus* Ash. (Hymenoptera: Scelionidae). Environ. Entomol. 14:323–328.

Wickman, B. E. 1976a. Phenology of white fir and Douglas-fir tussock moth egg hatch and larval development in California. Environ. Entomol. 5:316–320.

Wickman, B. E. 1976b. Douglas-fir tussock moth egg hatch and larval development in relation to phenology of grand fir and Douglas-fir in northeastern Oregon. USDA For. Serv. Res. Pap. PNW-206. 13 pp.

Wickman, B. E. 1981. Degree-day accumulation related to the phenology of Douglas-fir tussock moth and white fir over five seasons of monitoring in southern Oregon. USDA For. Serv. Res. Note PNW-392. 13 pp.